Using High Early Concrete or Accelerators

One Hot Topic

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Dave Figurski - LafargeHolcim
Tom McNamee - Master Builders Solutions
Introductions

- Dave Figurski - Tech Service Engineer, LafargeHolcim
- Tom McNamee - Mtn. Region Manager, Master Builders Solutions
- Matt McCombs - RMX Quality Manager, Martin Marietta
Why this presentation?

- Clarify terminology
- To get municipalities, specifiers, RMX suppliers, and contractors all on same page
- To help ensure contractors receive concrete performance they need
- Realistic expectations
**Basics of Cement Manufacturing**

**Main Ingredients:**
- \((\text{CaCO}_3)\) Limestone 65%  
- \((\text{SiO}_2)\) Sandstone 20%  
- \((\text{Al}_2\text{O}_3)\) Clay 15%  
- \((\text{Fe}_2\text{O}_3)\) Mill Scale < 2%

- \(\text{C}_3\text{S}\)
- \(\text{C}_2\text{S}\)
- \(\text{C}_3\text{A}\)
- \(\text{C}_4\text{A}\)

- Heat causes chemical changes in materials
- Changes are locked in place via rapid cooling (quenching)

Clinker
Basics of Hydration

- Cement reacts chemically with water, creating hydration products
- $C_3S$ - early strength development
  - Generates C-S-H (glue that holds concrete together)
- $C_3A$ - Heat of Hydration & Time of Set
  - Dissolving in water releases heat (Heat of Hydration...exothermic)
  - This crystal growth is responsible for setting of concrete

The effectiveness in these depend on:
- Quantity
- Rate of Reaction
How materials affect strength gain & time of set?

- **Cement**
  - Quantity in a yard
  - Physical Properties
    - Fineness
  - Chemical Properties
    - $C_3S$ content
    - $C_3A$ content

- **SCM’s - fly ash, slag, natural pozzolans**
  - Are not all the same...even within types
  - Typically reduce heat generation, set times, early strength
  - Generate more workable & durable concrete

Heat generation/conservation is critical!
How materials affect strength gain & time of set?

- **Water content simplified**
  - More water = easier to work with
  - More water = less strength/less durable

- **Admixtures...varies**
  - Can tailor the performance of the mix
  - Increase workability with the same w/c
  - Accelerators to decrease set times or increase strength development
  - Consult ready mix with any desired changes
How other conditions affect strength gain & time of set?

- Environment
  - Anything that reduces heat
    - Ground/ambient temps.
    - Shade
    - Frozen ground concerns
  - Infrared thermometers are handy
How other conditions affect strength gain & time of set?

- **Cure Temperatures**
  - What are you trying to accomplish??
- **Hydration is temperature/time dependent**
  - Maturity

### Table

<table>
<thead>
<tr>
<th></th>
<th>Total Cem. 750 III 0.40</th>
<th>705 @ 0.40 w/Acel</th>
<th>705 @ 0.45</th>
</tr>
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<tbody>
<tr>
<td>C150 Type III</td>
<td>564</td>
<td>705</td>
<td>705</td>
</tr>
<tr>
<td>95 IPN</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Class F Ash</td>
<td>141</td>
<td></td>
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<tr>
<td>3/4&quot;</td>
<td>1,493</td>
<td>1,450</td>
<td>1,450</td>
</tr>
<tr>
<td>Sand</td>
<td>1,250</td>
<td>1,215</td>
<td>1,235</td>
</tr>
<tr>
<td>Water</td>
<td>278</td>
<td>292</td>
<td>318</td>
</tr>
<tr>
<td>w/c</td>
<td>0.394</td>
<td>0.414</td>
<td>0.451</td>
</tr>
<tr>
<td>s/a</td>
<td>0.46</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>HRWR (oz/cwt)</td>
<td>5.0</td>
<td>5.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Accelerator (oz/cwt)</td>
<td>9.0</td>
<td>35.0</td>
<td>0.0</td>
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<tr>
<td>Air</td>
<td>5.0%</td>
<td>8.0%</td>
<td>6.2%</td>
</tr>
<tr>
<td>Slump (in)</td>
<td>8 1/4</td>
<td>9 3/4</td>
<td>8 1/4</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>18hr Heat Cure (achieved 100F)</th>
<th>18hr-(50F estimated)</th>
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</thead>
<tbody>
<tr>
<td>Individual Cylinder Breaks</td>
<td>4,580</td>
<td>4,800</td>
</tr>
<tr>
<td></td>
<td>3,100</td>
<td>3,320</td>
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<tr>
<td></td>
<td>3,110</td>
<td>3,160</td>
</tr>
<tr>
<td>0.75</td>
<td>4,690</td>
<td>3,240</td>
</tr>
<tr>
<td>7</td>
<td>8,360</td>
<td>7,790</td>
</tr>
<tr>
<td>15</td>
<td>5,000</td>
<td>8,170</td>
</tr>
<tr>
<td>28</td>
<td>9,163</td>
<td>8,443</td>
</tr>
<tr>
<td>7-D % of 28-D</td>
<td>91%</td>
<td>92%</td>
</tr>
<tr>
<td><strong>Averages</strong></td>
<td><strong>4,690</strong></td>
<td><strong>3,240</strong></td>
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<tr>
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<td>8,360</td>
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Measuring Set time (**Accelerated**)

- **Initial/Final Set (Penetration Resistance)**
  - Initial = 500 psi
  - Final = 4,000 psi
  - Not comparable to compressive strength

- **Finishing In Practice**
  - Support weight of finisher
  - ¼” shoe depression (15-25psi) before floating
    - Allows for mix stiffening & bleed water to cease
Measuring Strength (High Early)

- Measured in psi
- Minimum strengths req’d for opening structure
  - Opening road to traffic
  - Removal of formwork for elevated deck
- Time and Temp dependent (Maturity)
# Set Times

## Setting Time of Concrete at Various Temperatures

<table>
<thead>
<tr>
<th>Temperature °F</th>
<th>Setting Time hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>6</td>
</tr>
<tr>
<td>60</td>
<td>8</td>
</tr>
<tr>
<td>50</td>
<td>11</td>
</tr>
<tr>
<td>40</td>
<td>14</td>
</tr>
<tr>
<td>32</td>
<td>Freezes</td>
</tr>
</tbody>
</table>
Basics of Set Time

- **Final Set**
- **Initial Set**
  - Workability Retention
  - Waiting
  - Finishing Window
    - Powertrowel
    - Straightedge
    - Powerfloat
    - Hardening
    - Strength Gain

- **Hours**
  - Concrete Placement
  - Placing
  - Screeding
  - Bull Float
  - Straightedge
  - Workability Retention

- **Psi**
  - 0.5
  - 1
  - 1.5
  - 2
  - 2.5
  - 3
  - 3.5
  - 4
**Accelerated Set and High Early Strength - Levers to Pull**

Speed up the early hydration (heat gain) of concrete by using one or more of the following:

<table>
<thead>
<tr>
<th>Method</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Portland cement</td>
<td>Set HES</td>
</tr>
<tr>
<td>Use Type III Cement</td>
<td>Set HES</td>
</tr>
<tr>
<td>Hot water</td>
<td>Set</td>
</tr>
<tr>
<td>Heat Aggregate</td>
<td>Set</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>Set HES</td>
</tr>
<tr>
<td>Non-chloride accelerator</td>
<td>Set HES</td>
</tr>
</tbody>
</table>
Affects on Set Time

Cement Content on Setting Time

Concrete and Ambient Temperature: 50 °F (10 °C)

<table>
<thead>
<tr>
<th>Cement Content, lb/yd³ (kg/m³)</th>
<th>Initial Time of Set - Hours</th>
</tr>
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<tbody>
<tr>
<td>420 (250)</td>
<td>12:35</td>
</tr>
<tr>
<td>520 (310)</td>
<td>10:40</td>
</tr>
<tr>
<td>600 (355)</td>
<td>8:55</td>
</tr>
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Non-Chloride Effect Setting Time

Concrete and Ambient Temperature: 50 °F (10 °C)

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<td>10:40</td>
</tr>
<tr>
<td></td>
<td>7:45</td>
</tr>
<tr>
<td></td>
<td>8:55</td>
</tr>
<tr>
<td></td>
<td>7:05</td>
</tr>
</tbody>
</table>

Plain Concrete  Non-Chloride Accelerator
10oz/cwt
ACI 212.3 - Accelerating Admixtures for Concrete

- Reduce time to initial set
- Expedite the start of finishing operations
- Reduce the total time required for curing and protection
- Increase the rate of early strength development to permit earlier removal of forms and earlier opening of construction for service
Calcium Chloride

DON’T USE WHEN REINFORCING IS IN THE CONCRETE

- Don’t use with ASR potential Aggregates
- Don’t use with high sulfate soils present
- Don’t use with colored concrete
- Don’t use over 2% by weight of cement
Non-chloride Accelerators

- Non-Corrosive to reinforcing steel
- Accelerates setting time of concrete, allowing for faster completion of slabs
- Reduced in-place concrete costs
- Won't blotch colored concrete
- Can add more than 2% to get higher early strengths
How contractors order accelerator?

● Typically based on % Calcium Chloride
  ○ What is 1%?
  ○ What is 2%?

● Dose of Non-Chloride Accelerator
● Amount required for Same Set Time of Calcium Chloride under Same Conditions
● Predictable Set Time is what Contractors want
High Early Strength: Commercial Projects

Define what is required:
Hardened Properties
  X Strength at Y hours
Shrinkage
Permeability
Concrete temp

Plastic Properties
  Slump / Spread
Air Entrainment

Applications
  Foundation Walls
  Elevated Slabs
  Columns
  Beams
High Early Strength: Pavement Repairs

Freeways in need of repair and rehabilitation
Contractors face $$$ fines for delays in opening freeway
Commuter impatience with lane closures !!!
High Early Strength Data with Type III Cement

**Flexural Strength**  psi
- 4-hour: 480
- 24-hour: 855
- 28-day: 1250

**Compressive Strength**
- 4-hour: 4130
- 24-hour: 7740
- 28-day: 8250

**Fully-loaded truck on slab 4 hours after placement !!!**
Set Time For Finishing Concrete Flatwork – Mix Design

- Cement type and performance
  - Type I/II prevalent locally (Type III is available & sets faster)
- SCM type and performance
  - Locally C Ash, F Ash and RFA
- Total cementitious and SCM replacement content
  - Straight cement reacts faster
- Water to cementitious ratio
  - Affects strength and set time
- Addition of an Accelerator
  - Calcium Chloride or Non-Calcium Chloride
- Add more cement to the base mix
Set Time For Finishing Concrete Flatwork – Mix Design

Figure 4-2. General hydration curve delineating the five stages
Strength in Numbers

Set Time For Finishing Concrete Flatwork – Mix Design
Role of Temperatures & Environment on Performance

● Temperature
  ○ Ambient Temperature – Concrete seeks ambient temperature
  ○ Concrete Temperature – Strongly influenced by ambient and environmental temperature, which impacts set times and strength gain

● Environment
  ○ Cold ground, forms, pumps and reinforcement
  ○ Humidity, wind and sunlight = dried out surface & cracks
Concrete Set Time - Lab Trials vs. Field Performance

- Lab trials reflect near perfect conditions and constant temperatures
- Field performance is impacted by ambient temperature and environmental conditions
- What could be different??
Concrete Set Time - What to ask for or specify

- What to ask for or specify:
  - Ask for a place and finish plan
  - This will include:
    - Mix design and set time information
    - Anticipated weather
    - Field Conditions
    - Placement Method, etc.
  - Can be developed to maximize the opportunity for success.
  - Involve the Ready Mix supplier and the concrete finishers in a pre-pour meeting.
Strength Gain for Opening Structures or Pavements

- Plan for success
  - How high and how early?
  - Verify anticipated weather
  - Verify anticipated pour timeframe
  - Select a mix that will work based on these inputs
How critical is curing temperature?

- How can Maturity help?
What is concrete maturity?

- Concrete maturity is:
  - a non-destructive method to determine how far concrete hydration has progressed.
  - This is determined through the relationship of in place concrete temperature and time, which determines strength gain.

- A maturity curve is developed in a lab according to ASTM C1074.
What is concrete maturity?

- Loggers are then installed in a field placement and can be monitored to determine strength gain progress.
- The loggers provide a real time value that can be compared to the maturity curve in order to determine real time, in place strength.
Is your data accurate and dependable?

- The key to successfully placing high early concrete
  - Measure the strength accurately
  - Feel confident that your data is dependable
Review

- Faster Set for Finishing = Accelerated
- Early Strength for loading = High Early
- Material and Environmental conditions can both dramatically change mix performance
- Plan ahead
- Communicate your needs
Thank you for attending!

- Q/A Session

- Contact info:
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  - tom.mcnamee@mbcc-group.com
  - matt.mccombs@martinmarietta.com